CLAIMS

What is claimed is:

1. An excimer or molecular fluorine laser system, comprising:

a master oscillator including therein a first discharge chamber filled with a gas mixture, the first discharge chamber containing a plurality of electrodes connected to a first discharge circuit for energizing the gas mixture and generating an oscillator beam in the master oscillator, the master oscillator further including at least one window at an end of the first discharge chamber for sealing the first discharge chamber and for transmitting the oscillator beam;

a power amplifier including therein a second discharge chamber filled with a gas mixture, the second discharge chamber containing a plurality of electrodes connected to a second discharge circuit for energizing the gas mixture and amplifying the oscillator beam during a first pass through the power amplifier, the power amplifier further including at least one window at each end of the second discharge chamber for sealing the second discharge chamber and for receiving and transmitting the oscillator beam; and

a set of reflective optics capable of redirecting at least a portion of the oscillator beam, transmitted by the power amplifier, back through the power amplifier, such that the redirected portion of the oscillator beam is further amplified on a subsequent pass through the power amplifier.

2. A laser system according to claim 1, wherein:

the first and second discharge circuits comprise the same circuit.

3. A laser system according to claim 1, wherein:

the power amplifier is adjustable in order to reduce pulse-to-pulse energy fluctuations and improve the homogeneity in the oscillator beam.

4. A laser system according to claim 1, wherein:

the first discharge circuit is separate from the second discharge circuit, such that the power amplifier and the master oscillator can be separately optimized.

5. A laser system according to claim 1, wherein:

the set of reflective optics are further capable of redirecting at least a portion of the oscillator beam back through the power amplifier in order to stretch an effective length of the amplified pulse.

6. A laser system according to claim 1, further comprising:

a least one optical decoupler positioned along a path of the oscillator beam between the power amplifier and the master oscillator, the optical decoupler capable of at least one of reducing energy fluctuations and suppressing spontaneous emissions.

7. A laser system according to claim 1, further comprising:

a least one optical decoupler positioned such that the oscillator beam transmitted from the power amplifier passes through the decoupler prior to the subsequent pass of the oscillator beam through the power amplifier.

8. A laser system according to claim 1, wherein:

the master oscillator further includes a line-narrowing optics module for narrowing the oscillator beam in the first discharge chamber.

9. A laser system according to claim 1, wherein:

the master oscillator further includes an outcoupler module.

10. A laser system according to claim 1, further comprising:

a spatial filter positioned along a path of the oscillator beam between the master oscillator and the power amplifier, the spatial filter capable of at least one of optically decoupling the beam and modifying a width of the beam.

11. A laser system according to claim 1, further comprising:

a spatial filter positioned such that the oscillator beam transmitted from the power amplifier passes through the spatial filter prior to the subsequent pass of the oscillator beam through the power amplifier, the spatial filter capable of at least one of optically decoupling the beam and modifying a width of the beam.

12. A laser system according to claim 1, wherein:

the set of reflective optics includes at least one retro-reflector positioned after the power amplifier along a path of the oscillator beam, the retro-reflector being positioned at least one half pulse length away from the master oscillator in order to ensure that any photons originating in the oscillator and amplified in the power amplifier will not be further amplified in the master oscillator.

13. A laser system according to claim 1, wherein:

the set of reflective optics redirects at least a portion of the oscillator beam back through the power amplifier in a direction parallel to the direction of the first pass.

14. A laser system according to claim 1, wherein:

the set of reflective optics redirects at least a portion of the oscillator beam back through the power amplifier an angle relative to the direction of the first pass.

15. A laser system according to claim 1, wherein:

the set of reflective optics redirects at least a portion of the oscillator beam back through the power amplifier in a direction opposite to the direction of the first pass.

16. A laser system according to claim 1, wherein:

the set of reflective optics redirects at least a portion of the oscillator beam back through the power amplifier such that the redirected portion does not overlap the path of the beam on the first pass.

17. A laser system according to claim 1, wherein:

the set of reflective optics expands the portion of the beam redirected through the power amplifier such that the redirected portion removes stored energy from the remaining volume of a gain medium in the second discharge chamber not removed during the first pass.

18. A laser system according to claim 1, wherein:

the power amplifier includes therein a first discharge chamber filled with a gas mixture comprising a laser gas and a buffer gas.

19. A laser system according to claim 18, wherein:

the laser gas includes molecular fluorine.

20. A laser system according to claim 18, wherein:

the buffer gas includes one of neon and helium, the buffer gas capable of pressurizing the gas mixture in order to increase an output energy for a given input energy.

21. A laser system according to claim 1, further comprising:

at least one aperture positioned along a path of the oscillator beam for modifying the size of the beam.

22. A laser system according to claim 1, further including:

a gas supply system for transferring gas to the gas mixture for at least one of the first and second discharge chambers.

23. A laser system according to claim 22, further comprising:

a processing device in communication with the gas supply system capable of controlling the concentration of gas in the gas mixture for at least one of the first and second discharge chambers.

24. A laser system according to claim 1, wherein:

the set of reflective optics includes first and second polarizers positioned along a path of the oscillator beam after the beam makes the first pass through the power amplifier, the set further including first and second half-wave plates positioned along the path, such that the oscillator beam transmitted from the power amplifier on the first pass is directed by the first polarizer to pass through a first half-wave plate and be redirected by the second polarizer to make a second pass through the power amplifier, the second half-wave plate positioned after the second polarizer and before the first polarizer along the path such that the oscillator beam passes through the first polarizer after being transmitted from the power amplifier on the subsequent pass.

25. A laser system according to claim 1, wherein:

the set of reflective optics includes first and second polarizers positioned along a path of the oscillator beam after the beam makes the first pass through the power amplifier, the set further including a half-wave plate positioned along the path, such that the oscillator beam transmitted from the power amplifier on the first pass is directed by the first polarizer to pass through the first half-wave plate and redirected by the second polarizer to make a second pass through the power amplifier.

26. An excimer or molecular fluorine laser system, comprising:

a master oscillator including therein a first discharge chamber filled with a first gas mixture, the first discharge chamber containing a plurality of electrodes connected to a first discharge circuit for energizing the first gas mixture and outputting an oscillator beam;

a power amplifier capable of receiving the oscillator beam, the power amplifier including therein a second discharge chamber filled with a second gas mixture, the second discharge chamber containing a plurality of electrodes connected to a second discharge circuit for energizing the second gas mixture and amplifying the oscillator beam before transmitting the oscillator beam from the power amplifier;

a first set of optics for redirecting the oscillator beam transmitted from the master oscillator, the first set of optics positioned along a path of the beam between the master oscillator and power amplifier, and including a polarizing element for directing the beam through the power amplifier for a first pass of the oscillator beam through the power amplifier; and

a second set of optics for redirecting the oscillator beam transmitted from the power amplifier after the first pass of the oscillator beam through the power amplifier, the second set of optics positioned along a path of the oscillator beam after the power amplifier and including a wave plate for adjusting the polarization of the oscillator beam and a reflector for redirecting the oscillator beam back through the power amplifier, such that the redirected beam makes a second pass through the power amplifier and passes through the polarizing element.

27. A laser system according to claim 26, wherein:

the first and second sets of optics further includes at least one of a spatial filter and beam-shaping optics.

28. A laser system according to claim 26, wherein:

the second set of optics redirects the oscillator beam through the power amplifier such that the second pass substantially follows the path of the first pass through the power amplifier.

29. A laser system according to claim 26, wherein:

the second set of optics redirects the oscillator beam through the power amplifier such that the second pass passes through the power amplifier in a direction opposite the direction of the first pass.

30. A laser system according to claim 26, wherein:

the second set of optics redirects the oscillator beam through the power amplifier such that the second pass through the power amplifier occurs at an angle relative to the path of the first pass through the power amplifier.

31. A laser system according to claim 26, wherein:

a width of the oscillator beam is different during the first pass than during the second pass.

32. An excimer or molecular fluorine laser system, comprising:

a master oscillator including therein a first discharge chamber filled with a first gas mixture, the first discharge chamber containing a plurality of electrodes connected to a discharge circuit for energizing the first gas mixture and generating an oscillator beam in the master oscillator, the master oscillator further including at least one window at an end of the first discharge chamber for sealing the first discharge chamber and for transmitting the oscillator beam;

a power amplifier including therein a second discharge chamber filled with a second gas mixture, the second discharge chamber containing a plurality of electrodes connected to a discharge circuit for energizing the second gas mixture and amplifying the oscillator beam in the power amplifier, the power amplifier further including at least one window at each end of the second discharge chamber for sealing the second discharge chamber and for receiving the oscillator beam from the master oscillator and transmitting the oscillator beam; and

a set of optics for directing the oscillator beam transmitted from the master oscillator, the set of optics forming a ring structure about the power amplifier and including a partial reflectivity mirror for directing a first portion of the oscillator beam transmitted from the power amplifier through a beam matching unit for adapting a beam size of the first portion to a transmission size of the power amplifier, and at least one reflector for redirecting the first portion exiting the beam matching unit through the power amplifier in order to make a first pass through the power amplifier, the partial reflectivity mirror allowing a second portion of the first portion transmitted by the power amplifier to pass as an output beam, the partial reflectivity mirror redirecting a third portion of the first portion transmitted by the power amplifier toward the beam matching unit and at least one reflector such that the third portion makes a second pass through the power amplifier.

33. A laser system according to claim 32, wherein:

the beam matching unit is further capable of achieving a high spectral purity for the oscillator beam.

34. A laser system according to claim 33, wherein:

the beam matching unit includes a small aperture for transmitting a highly spatially coherent portion of the oscillator beam.

35. A laser system according to claim 32, wherein:

the beam matching unit is a two lens, positive branch telescope.

36. An excimer or molecular fluorine laser system, comprising:

a master oscillator including therein a first discharge chamber filled with a first gas mixture, the first discharge chamber containing a plurality of electrodes connected to a discharge circuit for energizing the first gas mixture and generating an oscillator beam in the master oscillator, the master oscillator further including at least one window at an end of the first discharge chamber for sealing the first discharge chamber and for transmitting the oscillator beam;

a pulse extender arrangement positioned along a path of the oscillator beam between the master oscillator and the power amplifier, the pulse extender arrangement including a beamsplitter and first and second highly reflective mirrors, the beam splitter directing a first portion of the oscillator beam transmitted by the master oscillator toward the power amplifier, and directing a second portion of the oscillator beam toward the first highly reflective mirror, the first and second highly reflective mirrors directing the second portion of the beam back toward the beam splitter such that a third portion of the second portion is transmitted to the power amplifier and a fourth portion of the second portion is directed back to the first highly reflective mirror, such that the transmitted third portion overlaps spatially with the first portion directed by the beam splitter;

a power amplifier including therein a second discharge chamber filled with a second gas mixture, the second discharge chamber containing a plurality of electrodes connected to a discharge circuit for energizing the second gas mixture and amplifying the first and third portions of the oscillator beam in the power amplifier, the power amplifier further including at least one window at each end of the second discharge chamber for sealing the second discharge chamber and for receiving from the master oscillator and transmitting the first and third portions; and

a set of reflective optics capable of redirecting at least a fifth portion of the first and third portions, transmitted by the power amplifier, back through the power amplifier, such that the redirected fifth portion is further amplified on a subsequent pass through the power amplifier.

37. A laser system according to claim 36, further comprising:

an optical isolator positioned along a path of the oscillator beam between the master oscillator and the pulse extender arrangement.

38. An excimer or molecular fluorine laser system, comprising:

a master oscillator including therein a first discharge chamber filled with a first gas mixture, the first discharge chamber containing a plurality of electrodes connected to a first discharge circuit for energizing the gas mixture and outputting an oscillator beam; and

a multi-pass amplifier capable of receiving the oscillator beam, the multi-pass amplifier including therein a second discharge chamber filled with a second gas mixture, the second discharge chamber containing a plurality of electrodes connected to a second discharge circuit for energizing the gas mixture and amplifying the oscillator beam during a each pass of the oscillator beam through the power amplifier, the power amplifier further including a set of reflective optics capable of redirecting at least a portion of the oscillator beam through the power amplifier for at least one subsequent pass.

39. An excimer or molecular fluorine laser system, comprising:

a master oscillator for energizing a gas mixture and outputting an oscillator beam; and

a multi-pass amplifier capable of receiving and directing the oscillator beam such that at least a portion of the oscillator beam is amplified over each of a plurality of passes through the amplifier.

40. A method of generating an output beam in an excimer or molecular fluorine laser system, comprising:

generating an oscillator beam in a master oscillator;

passing the oscillator beam on a first pass through a power amplifier, such that the oscillator beam is amplified;

directing at least a portion of the oscillator beam back to the power amplifier; and

passing the portion of the oscillator beam on a second pass through the power amplifier such that the portion of the oscillator beam is further amplified.

41. A method according to claim 40, further comprising:

transmitting an undirected portion of the oscillator beam as an output beam.

42. A method according to claim 40, further comprising:

using a least one optical decoupler positioned along a path of the oscillator beam between the master oscillator and the power amplifier, the optical decoupler capable of at least one of reducing energy fluctuations and suppressing spontaneous emissions.

43. A method according to claim 40, further comprising:

using a least one optical decoupler positioned along a path of the oscillator beam between the first and second passes of the oscillator beam through the power amplifier.

44. A method according to claim 40, further comprising:

using a line-narrowing optics module to narrow the oscillator beam in the master oscillator.

45. A method according to claim 40, further comprising:

using a spatial filter to optically decouple the beam and modify a width of the beam.

46. A method according to claim 40, further comprising:

controlling a concentration of gas in at least one of the power amplifier and master oscillator.

47. A method of generating an output beam in an excimer or molecular fluorine laser system, comprising:

generating an oscillator beam in a master oscillator including therein a first discharge chamber filled with a gas mixture, the first discharge chamber containing a plurality of electrodes connected to a first discharge circuit for energizing the gas mixture to generate the oscillator beam, the master oscillator further including at least one window at an end of the first discharge chamber for sealing the first discharge chamber and transmitting the oscillator beam;

receiving the oscillator beam to a power amplifier including therein a second discharge chamber filled with a gas mixture, the second discharge chamber containing a plurality of electrodes connected to a second discharge circuit for energizing the gas mixture and amplifying the oscillator beam during a first pass through the power amplifier, the power amplifier further including at least one window at each end of the second discharge chamber for sealing the second discharge chamber and for receiving and transmitting the oscillator beam; and

positioning a set of reflective optics in the path of the oscillator beam transmitted from the power amplifier such that at least a portion of the oscillator beam transmitted by the power amplifier is directed back through the power amplifier, such

that the redirected portion of the oscillator beam is further amplified on a subsequent pass through the power amplifier.